The effect of feeding pellets, meal and heat treatment on the salmonella-prevalence in finishing pigs

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Introduction

A previous trial (1) has shown that meal reduces the *Salmonella* prevalence and the degree of stomach changes as compared with pelleted feed. It was also found that coarsely ground feed tended to reduce the *Salmonella* problem compared with finely ground feed. The type of feed that reduced the *Salmonella* prevalence resulted in a substantially poorer feed conversion. There is a need to clarify what the feed industry can do to produce feed that reduces the risk of *Salmonella* problems and gastric changes and at the same time to clarify the effect on feed conversion.

Thus, the object of the study was to clarify the effect of the pelleting process and the expansion of grain on the proportion of serological reagents against *Salmonella* and on gastric health and production result in finishing pigs.

Materials and Methods

The trial was carried out in a herd with finishing pigs, one section per week being filled. The pigs were randomly distributed but so that the six pens of each replication had the same distribution of sex and average weight of entry (about 29 kg). The trial was carried out in three houses, each divided into two sections and designed with fully slatted flooring. Each section had 12 pens with open pen partitions -in the trial the pens had 16 pigs each. Each pen was provided with a dry feeder and a drinking bowl per pen, and no bedding was used. The feed was weighed out for each pen and given on an ad lib. basis. The trial comprised six groups, cf. Table 1.

Table 1. Survey of the six groups included in the trial

Group	Degree of grinding*	Heat treatment of grain in expander	Pelleting	Type of feed
Group 1	Fine	Yes	Yes	Fine pellets
Group 2	Coarse	Yes	Yes	Coarse pellets
Group 3	Coarse	No	Yes	Cold-pressed pellets
Group 4	Coarse	Yes	No	Expanded feed
Group 5	Coarse	No	No	Meal
Group 6	Coarse	2/3 of grain	Yes/No**	Partially heat-treated feed

In all groups the protein part was heat-treated to above 81°C. Thus, heat treatment and pelleting are only relevant for the grain part. The feed contained no antibiotic growth promoter, and the copper content was 35 ppm

* The finely ground feed was ground on a 2 mm screen (particle distribution, < 1mm, 1-2 mm, 2-4 mm, >4 mm: 87/13/0.4/0) , and the coarsely ground feed was ground on a 4 mm screen (particle distribution: 47/37/18/0)

** The protein part and two thirds of the grain were ground, compressed into pellets, cooled, and the pellets were granulated back into the mixer. The last third of the grain was ground into the mixer at the same time, and the feed was delivered as meal.

Recordings

Production results and slaughter data were recorded during the trial period. Immediately before delivery of the first pigs from the pens, blood samples from six pigs selected at random from each pen were tested for antibodies against *Salmonella*. Each group provided 15 manure samples to be tested for starch and *Salmonella*. Feed samples (without manure contamination) were collected from the feeders from all the pens in the first 24 replications. Sampling took place right after entry of the pigs, at six weeks after entry and immediately before slaughter. These samples were analysed for microbiological activity by the Danish Institute of Agricultural Sciences. The particle distribution of the grain part was also examined.

At slaughter, the stomach and caecal contents were sampled for bacteriological examination and for analysis for contents of organic acids as well as dry matter and pH (about 20 samples per group). The consistency of the stomach contents was assessed visually, and pathological changes in the Pars proventricularis were examined in about 100 stomachs per group.

Statistics -Salmonella

The effect on the *Salmonella* prevalence was assessed as the proportion of blood-sampled pigs having an OD-value exceeding 40 (which is used in the Danish salmonella surveillance programme). The result was analysed in a logistic regression model with the proportion of positive samples per pen as a dependent variable, and the feed mix and average *Salmonella* reaction in the section as explanatory variables. It was examined whether a mathematical transformation of the average *Salmonella* reaction would improve the statistical model, and a logarithmic transformation would improve the model. Presumed clustering at pen level was corrected by means of the p-scale option in the SAS procedure Genmod.

The analysis was carried out in two stages. At stage 1, it was examined whether the *Salmonella* prevalence differed significantly depending on feed mix. If this analysis showed a significant difference, further analyses were carried out at stage 2 to examine whether the difference could be explained by the physical characteristics of the six mixes. The following hypothesis was thus drafted: The *Salmonella* prevalence depends on feed texture (coarse/fine), form (pellets/meal) and/or heat treatment (heat-treated grain part, partially heat-treated grain part and non-heat-treated grain part). The hypothesis was tested in a logistic regression model with texture, form, heat treatment, interaction between form and heat treatment and the logarithm of the average *Salmonella* reaction in the individual section.

The result of the regression models is stated as relative risk. The relative risk is here a calculated, approximated relative risk (odds ratio).

Statistics -Production results and value

GM/pen place/year was calculated on the basis of the production results measured, adjusted to the same weight at entry, and was statistically analysed by means of a variance analysis in the GLM procedure in SAS. The statistical model included the following class variables: test round, section, section within test round, batch within section and test round as well as group. All six treatments were compared with each other. A Bonferroni adjustment was made for 15 paired comparisons. Significant differences are stated at the 5 per cent level.

Results

Salmonella

The proportion of pigs having a blood sample reaction against *Salmonella* (sero-positive pigs) depended on the feed type, cf. Table 2. An overall statistical analysis showed a significant difference on the proportion of sero-positive pigs depending on the feed mix used, when adjustment was made for the pressure of infection in the individual sections ($p<0.0001$).

Table 2. Proportion of positive blood samples per group

Group	1 Fine pellets	2 Coarse pellets	3 Cold-pressed pellets	4 Expanded feed	5 Meal	6 Partially heattreated feed
Positive, total Positive, %	36 12.9	16 5.6	24 8.6	13 4.6	8 2.8	13 4.6
Samples, total	280	284	279	285	282	285

Table 3 shows the result of the statistical analysis for the effect of degree of grinding, pelleting and heat treatment of the feed. The analysis showed that the effect of texture was significant. A pig fed with finely ground feed had a risk 3.33 times greater of being seropositive than a pig fed with coarsely ground feed. Pigs fed with pelleted feed had a risk 3.33 times greater than pigs fed with non-pelleted feed. There was no significant effect of the degree of heat treatment.

An examination of whether the effect of form (pelleted/non-pelleted) depended on heat treatment (interaction between heat treatment and form) showed interaction close to being significant (p=0.07). The dependency between heat treatment and the effect of pelleting on the proportion of sero-positive animals was therefore examined in more detail. If the grain part was not heat-treated, the risk of a sero-positive pig was 7.63 times greater when the feed was pelleted than when the feed was not pelleted. When the grain part was heat-treated, no significant effect of pelleting could be proved. The conclusion is that the significant difference between pelleted feed and non-pelleted feed can be explained by the difference between cold-pressed pellets and non-heat-treated meal, whereas the difference between heat-treated pelleted feed and expanded meal is not significant. It was not possible to demonstrate a significant effect of different degrees of heat treatment depending on whether the feed was pelleted or meal.

Salmonella (*S. Typhimurium*) was only found in three manure samples, and these results have not been statistically analysed.

Microbiological analysis of the feed

No *Salmonella* was found in any of the feed samples examined (a total of 432 samples). The different feed types differed markedly in their amounts of bacteria. The largest populations of bacteria (aerobic bacteria, coliform bacteria and yeast cells) were found in the meal followed by the partially heat-treated feed, whereas the occurrence of bacteria in the other four feed mixes was relatively low.

Table 3. Importance of texture, form and heat treatment to the number of pigs serologically positive for *Salmonella*

		Relative risk	95 per cent confidence limits*	P value
Texture	Fine Coarse	3.33 1	1.36-8.16	0.0014
Form	Pellet Meal	3.33 1	1.42-7.81	0.0007
Heat treatment of grain	Full Partial No heat	0.87 1.27	0.39-1.96 0.40-3.98	0.7445

* 95 per cent confidence limits state the certainty of the relative risk. It is 95 per cent certain that the relative risk measured will be within these limits.

Production results

The production results obtained appear from Table 4.

Based on the production results obtained, the production value was calculated at the same price for all feed mixes, cf. Table 4. The figures show that the different feed mixes divide into three groups. Group 1, where the pigs received the finely ground pellets, managed significantly best. There was no significant difference in production value between the groups receiving coarsely ground pellets and cold-pressed pellets (groups 2 and 3), so it was of no importance to the pigs' production results whether the grain part was expanded or not. Pigs receiving one of the three non-pelleted types of feed (groups 4, 5 and 6) managed significantly poorest, and there was no difference in production value obtained between the three groups. As shown by the figures, feed conversion in particular was the cause of the poorer production value.

Dry matter, pH and consistency in stomach

Dry matter in stomach contents, pH and consistency appear from Table 5.

Table 4. Production results

Group	1 Fine pellets	2 Coarse pellets	3 Cold-pressed pellets	4 Expanded feed	5 Meal	6 Partially heattreated feed
Batches, total	45	46	47	43	48	46
Pigs produced	686	702	717	659	741	713
FUs/pig/day	2.24	2.32	2.31	2.36	2.45	2.42
Daily gain, g	812	793	794	764	791	797
FUs per kg of gain	2.77	2.92	2.92	3.08	3.09	3.04
Lean meat percentage	59.5	59.6	59.8	59.8	59.7	59.6
Production value[1]						
GM/pen place/year, DKK	379a	315b	318b	241c	253c	270c
Index	100	83	84	63	67	71
Starch in manure, percentage of dry matter	0.22	1.7	1.9	4.8	5.7	2.2

[1] The difference in production value has to be at least DKK 36.9 per pen place per year or a minimum of 10 index points for the difference to be significant
a, b, c: results with different letters differ significantly

Table 5. Dry matter in stomach contents, pH and consistency assessed visually at slaughter

Group	1 Fine pellets	2 Coarse pellets	3 Cold-pressed pellets	4 Expanded feed	5 Meal	6 Partially heattreated feed
Average score for consistency of stomach contents*	1.2a	1.5b	1.4b	1.8c	2.1d	1.6b
Dry matter in stomach con-tents, %	10.3c	17.2ab	14.1bc	19.1ab	21.3a	14.0bc
pH in the stomach	4.19a	3.25b	3.83ab	4.00ab	3.60ab	3.71ab

*A scale from 1 to 3 has been used, the score 1 being liquid stomach contents and the score 3 being firm stomach contents
a, b, c, d: results with different letters differ significantly

Effect on the microbial ecosystem measured in stomach and caecum

The population of lactic acid bacteria in **stomach contents** was largest in pigs receiving meal and relatively large in pigs given expanded feed. The smallest populations of coliform bacteria in the stomach were generally found in pigs given meal, partially heat-treated feed and expanded feed. The different types of feed did not substantially affect the yeast population in the stomach contents. Generally, the concentration of lactic acid was highest in stomach contents from pigs receiving expanded feed and meal, and lowest in pigs receiving the finely and coarsely ground pellets. As regards both acetic acid, propionic acid and butyric acid, the concentrations were significantly higher in pigs receiving meal than in pigs receiving the other types of feed.

No differences were recorded in the dry matter content of **caecal contents** from pigs receiving the six types of feed. On the other hand, pH was significantly higher in pigs receiving finely ground pellets than in pigs receiving the other five types of feed. The lowest pH was measured in pigs receiving expanded feed and meal. The population of lactic acid bacteria in caecal contents was not affected by type of feed. On the other hand, the population of coliform bacteria was significantly higher in the caeca of pigs receiving the finely ground pellets and the partially heat-treated feed than in pigs receiving expanded feed and meal. The results do not indicate that the different types of feed affect the yeast population in caecal contents. The concentration of acetic acid was significantly lower in the caeca of pigs receiving finely and coarsely ground pellets than in pigs in the other groups. Also, the concentrations of propionic acid and butyric acid were lower in the caeca of pigs receiving the finely ground pellets than in pigs in the other groups. On the other hand, the concentration of isobutyric acid was higher in the caeca of pigs receiving the finely ground pellets than in pigs receiving the other types of feed.

Gastric health

The average score for gastric lesions in the Pars proventricularis appears from Table 6. The results found correlate well with previous findings (1, 2).

Discussion

The results of this trial show, in correlation with previous experiments, that non-heat-treated meal lowers the prevalence of *Salmonella* in finishing pigs compared with pelleted feed. The reason for this seems to be that non-pelleted feed results in a microbiological ecosystem that provides *Salmonella* with poor conditions of growth compared with pelleted feed (especially at a fine degree of grinding). The results furthermore show that it is not sufficient to omit to heattreat part of the grain to optimise the microbial ecosystem in the gastro-intestinal tract and that the natural microbial flora of the feed is of no importance to a good gastro-intestinal environment.

Altogether, the trial shows that the feed mixes that reduced the *Salmonella* prevalence and/or had a positive effect on gastric health and the microbial ecosystem had a negative effect on production results. This experiment thus does not provide any basis for unambiguous directions for a production process that benefits both the microbial ecosystem of the pigs (including gastric health) and production economy. Work now continues to examine the possibility of improving production economy without any adverse effects on gastric health and *Salmonella* prevalence.

References

1. Kjeldsen N. The effect of feeding non-heat treated, non-pelleted feed compared to feeding pelleted, heat-treated feed on the salmonella-prevalence of finishing pigs. 1999. Third International Symposium on the Epidemiology and Control of Salmonella in Pork.

2. Nielsen, E. Keller. Effect of feed on stomach volume, consistency of stomach content, ulcers and production results in pigs. 1998. Report No. 4, Danish Institute of Agricultural Sciences.

Table 6. Gastric health

Group	1 Fine pellets	2 Coarse pellets	3 Cold-pressed pellets	4 Expanded feed	5 Meal	6 Partially heattreated feed
Stomachs examined, total	102	118	122	110	121	95
Average stomach index	2.9a	1.7b	1.7b	0.3cd	0.08d	1.0c
Pigs with index > 5, total	17	7	5	3	1	3

a, b, c, d: results with different letters differ significantly.